



Figure 4.14 – Munition demilitarization building exhaust filter system

High-risk operations often require segmented systems with two or more housings ducted in parallel that exhaust from the same area and vent to the same stack. Each housing must have inlet and outlet isolation dampers to permit one to be held in standby or, when both are normally operated simultaneously, to allow one housing to be shut down for maintenance, testing, and emergencies.

Another important consideration in housing layout is uniformity of airflow through the installed components. This is especially important for adsorbers, since flow through those components must achieve the gas residence time required for efficient adsorption of radioactive organic iodine compounds. For large, multiple-filter housings that must operate in parallel, equalizing screens may be required in each filter unit to ensure uniform flow in housings. Long transitions are difficult, particularly in large housings. Nevertheless, every effort should be made to locate and design inlets and outlets to avoid stratification and to enhance the uniformity of airflow through components.

Special care must be taken in designing side-access housings to ensure uniform flow through all filter elements. It is recommended that manufacturers performance-test prototype side-access filter units in accordance with ASME AG-1, Section TA,²⁶ to document uniformity of flow through side-access filter units before fabrication of production units. When high-activity alpha-emitters such as plutonium or transuranic elements are handled, it may also be

desirable to compartment the system both in series, with separate housings for prefilters and HEPA filters, and in parallel for extra safety.

4.3 COMPONENT INSTALLATION

4.3.1 GENERAL

Proper installation of HEPA filters, adsorber cells, and demisters are critical to the reliable operation of a high-efficiency air cleaning system. HEPA filter and adsorber frames should be designed in accordance with the requirements of ASME AG-1, Section FG.²⁵

4.3.2 CONSIDERATIONS

Factors that must be considered in designing such installations include:

- Structural rigidity of mounting frames
- Rigid and positive clamping of components to the mounting frame
- Careful specification of and strict adherence to close tolerances on alignment, flatness, and the surface condition of component seating surfaces
- Welded-frame construction and the welded seal between the mounting frame and housing
- Ability to inspect the interface between components and the mounting frame during installation (man-entry)
- Adequate spacing between components in the bank (man-entry)
- Adequate spacing in the housing for men to work (man-entry).

4.3.3 HOUSING CONSTRUCTION

The components and mounting frame should form a continuous barrier between the contaminated and clean zones of the system. Any hole, crack, or defect in the mounting frame or in the seal between components and the frame that permits bypassing will result in leakage of contaminated air into the clean zone and reduced system effectiveness. A mounting frame that is not sufficiently rigid can flex so much during

operation, particularly under abnormal conditions, that leaks may develop in the HEPA filters clamped to the frame (due to differential flexing of the filter case relative to the mounting frame). Cracks may also be opened between the filters and the frame, between frame members (due to weld cracking or fatigue), or between the frame and the housing. Insufficient attention to maintenance provisions in the original design can increase operating costs and reduce the reliability of the system. Once the system is installed, defects are difficult to locate, costly to repair, and may even require rebuilding the system.

Mounting frames for HEPA filters and other critical components should be all-welded structures of carbon or stainless steel structural shapes. Carbon steel frames should be painted or coated for corrosion resistance. Galvanized steel is not recommended because of welding difficulties and because the zinc coating does not give adequate protection in the environments that may be encountered in a contaminated exhaust system. Aluminum is not recommended. Because of the high cost of surface preparation, inspection, and rework usually incurred in obtaining high-quality vinyl and epoxy coatings, stainless steel is often the best and most economic choice for radiochemical plant applications. Suitable mounting frame materials include the following (source references are listed at the end of this chapter as noted below):

- Stainless steel shapes, ASTM A479, Type 304L, class C, annealed and pickled⁶
- Stainless steel plate, ASTM A240, Type 304L, hot-rolled, annealed, and pickled⁷
- Stainless steel sheet, ASTM A240, Type 304L, annealed and pickled, 2D or 2B finish⁷
- Carbon steel shapes and plate, ASTM A36,² A499³
- Carbon steel structural tubing, ASTM A500⁴
- Carbon steel sheet, ASTM A245,⁵ grade D

Information relating to fabrication includes:

- "Specification for the Design, Fabrication, and Erection of Structural Steel for Building," *Manual of Steel Construction*⁹
- *Allowable Stress Design*, American Institute of Steel Construction, New York, 1989.
- *Light-Gage Cold-Formed Steel Design Manual*,¹³ American Iron and Steel Institute, New York, 4th ed., 1962.
- *AWS Structural Welding Code-Steel*,²³ AWS D1.1, American Welding Society, Miami, 2002.
- *Design of Welded Structures*,¹⁹ O.W. Blodgett, James F. Lincoln Arc Welding Foundation, Cleveland, 1976.

4.3.4 POTENTIAL HOUSING LEAKAGE

Contaminated filter housings must be leaktight to prevent contamination of adjacent service and operating areas. Although it is commonly assumed that all leakage will be in-leakage in a negative pressure system, out-leakage can occur under some conditions, even when the system is operating at its design negative pressure and particularly when the system is down. Leak-testing of filter housings is covered in Chapter 8.

The design of nuclear air cleaning system housings must consider the potential for leakage. By locating the filter unit in an appropriate plant location and locating the blower relative to the filter housing, leakage amounts, especially leakage of contaminated air, can be minimized. Further, quality construction of the filter housing and filter frames can additionally reduce leakage.

For example, a once-through contaminated exhaust filter housing serving a radioactive waste handling area in a nuclear power plant may be designed with the exhaust fan located after the filter housing and the housing located in a space that is "cleaner" than the air entering the housing. The benefit of this system configuration is that the air cleaning system up to the fan is under a negative pressure. Leakage is into the housing, thereby minimizing the potential impact of contaminated leakage on plant personnel during system operation. This system configuration does not mean leakage

should not be considered. It means that the leakage potential can be reduced by component location and that further reductions in personnel dose to levels as low as reasonably achievable (ALARA) are possible via housing construction.

If the space where an air cleaning system housing is located were more contaminated than the air entering the housing, it would be better to locate the fan on the inlet side of the housing. This arrangement would eliminate in-leakage of more contaminated air downstream of the filters.

For a habitability system where the housing is located within a protected space, the fan should be located downstream of the filter unit to ensure any potential in-leakage is "cleaner" air. If the housing in a habitability system is located in an area outside the protected space, then the fan should be located upstream of the filter unit to ensure potentially contaminated air does not bypass the filter unit.

This philosophy of locating fans and housings can be summarized as follows: If the relative atmosphere within an area is cleaner than another area or duct, the first is given a positive sign (+) and the more contaminated area a negative sign (-). The actual pressure within an air cleaning housing should also have the same sign. If the sign is positive, the fan should be on the air-entry side; if the sign is negative, the fan should be on the air cleaning side.

Thus, the first step in determining housing leaktightness is to assess the relative contamination potential between the air entering the housing and the space where the housing is situated. Locate the fan accordingly, then determine the allowable leak rate to maintain (1) the personnel dose within the requirements of 10 CFR 20²⁴ for in-plant personnel, (2) the offsite dose per 10 CFR 100,²⁵ and (3) the ability of the system to maintain performance [e.g., direction of airflow, required pressure differential, air exchange (dilution) rates]. The latter item depends on the system design and margin. ASME N509-89¹ and ASME AG-1, Section HA,²⁶ provide guidance on determining allowable leakage.

The allowable leakage should be considered when determining the construction requirements.

However, for filter housings, usually the structural design requirements for pressure and dynamic forces dictate that the housing fabricated of heavy platework (10-gage to 3/16-inch-thick) can be seal-welded to join the transverse and longitudinal joints instead of using bolts without significantly increasing cost. This will result in a low-leakage installation.

4.3.5 PAINTS AND PROTECTIVE COATINGS

Coating and paint requirements must be consistent with the corrosion expected in a particular application and the size of the duct. Corrosion and radiation-resistant paints and coatings should, at minimum, meet the requirements of ANSI N512²⁷ for "light exposure." Unless special spray heads are used, spray coating the interior of ducts smaller than 12-in.-diameter is often unreliable because it is difficult to obtain a satisfactory coating and inspect for defects and "holidays." The interior of ducts 8 in. and smaller cannot be satisfactorily brush-painted; instead, dip coating is recommended. Ducts to be brush-painted should be no longer than 5 or 6 ft to ensure proper coverage.

The mounting frame and housing interior of carbon steel must be painted to protect against corrosion and to facilitate cleaning and decontamination. Surfaces must be prepared properly, and primer and topcoats must be applied in strict accordance with the paint manufacturer's directions to obtain the necessary wet-film and dry-film thicknesses. Film thicknesses should be tested during and after application. Steel surfaces should be abrasive-blasted to white metal to a profile of 1 to 2 mils in accordance with Surface Preparation Specification 5 of the *Steel Structures Painting Manual*.²⁵ The prime coat must be applied within 2 to 3 hrs after grit-blasting, and in no case should be delayed to the next day. Hand- or power-tool cleaning (Surface Preparation Specifications 2³² and 3³³ of the Steel Structures Painting Council) is usually sufficient for exterior steel surfaces. Ambient temperature and metal temperature should be at least 10 to 20 degrees Fahrenheit (6.6 to 12.2 degrees Celsius) above the dew point before starting to paint, and there must be adequate drying time between

coats. Thick runs and streaks must be avoided, particularly on gasket seating surfaces where they may chip off and leave uneven surfaces that will interfere with proper sealing of the filter. After painting, gasket seating surfaces should be coated with a silicone oil or grease to prevent the filter gasket from adhering to the paint after a period of service. Clamping bolts should not be painted because the paint will scrape off and jam the nuts. Threads should be masked during painting and then coated with silicone grease.

High-build epoxy-polyamide and modified phenolic coating systems have proven satisfactory for interior steel and masonry surfaces. Although inorganic zinc primers are often recommended for steel, their use is not recommended for housing interiors because the zinc particles are difficult to hold in suspension properly and they tend to surface, causing blistering and peeling of the top coats.²⁶ An airless spray is recommended for applying prime and top coats. Guidance for selecting coatings and paints for nuclear service is given in ANSI N512.²⁷ For selection purposes, the classification "moderate exposure" is recommended for high-activity (or potential high-activity) systems, and the classification "light exposure" is recommended for low-activity systems. The recommendations on quality assurance during application of paints and coatings given in ANSI N101.4²⁸ are suggested for Engineered Safety Feature (ESF) and other high-activity (or potential high-activity) systems.

Inorganic zinc primers are acceptable for exterior steel surfaces, but complete curing may take from two days to six weeks, depending on temperature and humidity conditions. One or two coats of high-build epoxy, vinyl, acrylic, or silicone paint are recommended for exterior steel surfaces exposed to the weather. Epoxy-polyamide coatings are superior to epoxy amines for water and salt resistance and have better tolerance for moisture during application. Vinyls are excellent for general marine and chemical plant exposures and do not chalk as much as epoxies when exposed to sunlight. On the other hand, they are inferior to epoxies in abrasion resistance, solvent resistance, and

resistance to severe water or brine splashing. For outdoor service, acrylic coatings give the best protection against chalking and discoloration from sunlight and ultraviolet, but are suitable only as topcoats over an intermediate epoxy or vinyl coating. Silicone-based paints are useful for high-temperature applications, and aluminum-filled silicones give good protection up to 1,000 degrees Fahrenheit (537.8 degrees Celsius). For a housing or duct that is located indoors and is exposed only to normal building atmospheres, an acrylic paint is suitable and gives good protection against color fading.

Because of difficulties in applying high-quality coatings and their often-unsatisfactory performance, the designer should seriously consider stainless steel for mounting frames and housings in applications where corrosion or frequent decontamination will be encountered. Although quoted prices for carbon steel construction with high-quality coating systems generally run about 20 to 25 percent of the cost of stainless steel construction, experience shows that delays and difficulties in proper application frequently raise the final cost of coated carbon steel to as much as or more than stainless steel. Further references for painting include ASTM D3912,²⁹ D3911,³⁰ D3843,³¹ and N101.2.³²

4.4 MAN ENTRY HOUSING

4.4.1 GENERAL

Steel man-entry housings may be shop-built or field-fabricated. The trend, particularly in ESF systems, is increasingly toward shop-built steel housings. Stainless steel is the most common material of construction; however, carbon steel also may be used. Aluminum and galvanized steel are not suitable.

4.4.2 STRUCTURAL

The mounting frame is a statically indeterminate lattice that generally consists of a set of full-length members spanning the height or width of the bank (whichever is shorter), connected by cross members that are slightly shorter than the width of individual filter (adsorber) units. For design purposes, the frame may be considered as